

Lecture Module - Data Acquisition

ME3023 - Measurements in Mechanical Systems

Mechanical Engineering

Tennessee Technological University

Module 8 - Data Acquisition

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- Topic 1 - Analog to Digital Conversion
- Topic 2 - DAQ Hardware and Applications
- Topic 3 - Sampling and Aliasing

Topic 1 - Analog to Digital Conversion

- DAQ and Computer Storage
- Number Types
- Analog to Digital Conversion and DAQ
- Activity: ADC Resolution Calculation

DAQ and Computer Storage

Types of Signals:

- **Analog** - magnitude is continuous in time
- **Discrete Time** - magnitude at points in time
 - sampling at repeated time intervals
- **Digital** - exists in discrete points in time
 - magnitude is also discrete

DAQ and Computer Storage

A data acquisition system is the portion of a measurement system that quantifies and stores data. - Theory and Design of Mechanical Measurements

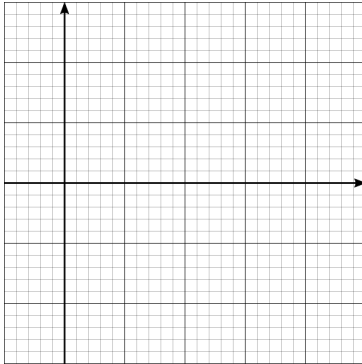


Image: T.Hill

Number Types

- Integers
 - Binary
 - Decimal
 - Hexadecimal
- Fixed Point
- Floating Point

Number Types

Binary	Decimal	Hexadecimal
0	0	0
1	1	1
10	2	2
11	3	3
100	4	4
	5	5
	6	6
	7	7
	8	8
	9	9
	10	A
	11	B

Binary	Decimal	Hexadecimal
	12	C
	13	D
	14	E
	15	F
	16	
	17	
	18	
	19	
	20	
	21	
	22	
	23	

some reference

Number Types

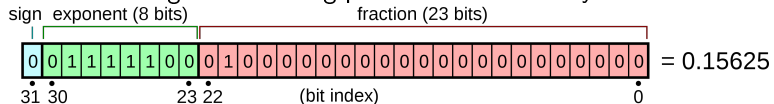
Binary	Decimal	Hex.
0	0	0
1	1	1
10	2	2
11	3	3
100	4	4

some reference

Binary	Decimal	Hex.
0	0	0
1	1	1
10	2	2
11	3	3
100	4	4

Number Types

Standard storage of a floating point value in memory



Number Types

Integer

Pros:

Cons:

Examples:

Floating Point

Pros:

Cons:

Examples:

Fixed Point

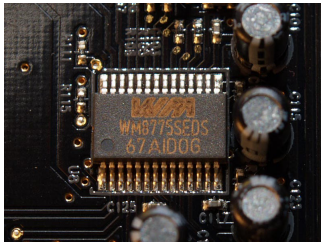
Pros:

Cons:

Examples:

Analog to Digital Conversion and DAQ

In electronics, an **analog-to-digital converter** (ADC, A/D, or A-to-D) is a system that converts an analog signal, such as a sound picked up by a microphone or light entering a digital camera, into a digital signal. An ADC may also provide an isolated measurement such as an electronic device that converts an analog input voltage or current to a digital number representing the magnitude of the voltage or current. Typically the digital output is a two's complement binary number that is proportional to the input, but there are other possibilities.



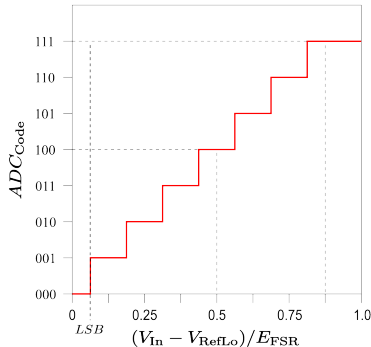
[wikipedia, image](#)



Analog to Digital Conversion and DAQ

Activity: ADC Resolution Calculation

It is important to realize the potential for data loss resulting in a reduced quality measurement based on the parameters of the analog to digital conversion process. This issue can occur when designing systems around a low-level analog to digital converter as well as when using high-end DAQ equipment.



Activity: ADC Resolution Calculation

Activity: - Consider setting up a data acquisition system to record pressure measurements in a vehicle system. Multiple sensors are available, and the DAQ device has different operating modes. Each sensor and DAQ mode has a different input and output signal ranges and different sampling frequencies.

Signal

- Measure Variable: Pressure (psi) in automobile tire
- Expected Range: 0-100 psi

Sensor+Transducer	Input Range (psi)	Output Range (volts)
A	0-200	0-3.0
B	0-120	0-0.50
DAQ Mode	Input Range (volts)	ADC Resolution
1	0 to 3.3	10bit
2	0 to 10	12bit

Activity: ADC Resolution Calculation

Activity (continued):

- 1 Choose a **sensor+transducer** pair and an appropriate **DAQ mode** to record the signal shown with best (lowest) possible resolution. Support your choices with a resolution calculation for smallest detectable voltage (*volts*) and smallest detectable pressure (*psi*)
- 2 Approximate the sensitivity of the measurement system in units of $\frac{psi}{volts}$.

Topic 2 - DAQ Hardware and Applications

- Signal Types and DAQ
- EMI Considerations
- Available Hardware
- Software Integration

Signal Types and DAQ

Most data acquisition devices and systems measure and record **analog** voltage signals and possibly additional signal types. Signal **generation** may also be a feature on some systems.

A voltage signal requires a **common** reference or **ground**.

Signal Sources:

- Grounded or Ground-Referenced
- Ungrounded or Floating

Measurement (DAQ) Systems:

- Common Ground
- Common Mode Voltage
- Isolated Ground

Signal Types and DAQ

Most data acquisition devices and systems measure and record **analog** voltage signals and possibly additional signal types. Signal **generation** may also be a feature on some systems.

2 Major Configurations:

- Single-Ended Signals

The signal is measured as a voltage between a **single** conductor and the **ground** which must be carried on a separate conductor or wire.

- Double-Ended (Differential) Signals

The signal is measured as the **difference** between two voltages (**double**) carried on separate conductors, or wires. Typically a **ground** is shared between the two devices requiring a third conductor.

Signal Types and DAQ

Single-Ended Signals

Pros:

Cons:

Examples:

Double-Ended Signals

Pros:

Cons:

Examples:

EMI Considerations

Electromagnetic interference (EMI), also called radio-frequency interference (RFI) when in the radio frequency spectrum, is a disturbance generated by an external source that affects an electrical circuit by electromagnetic induction, electrostatic coupling, or conduction.

A *combination* of naturally occurring and human made sources of interference is always present. The total EMI affecting a system is determined by the local conditions as well as global environmental influences.

Sources of EMI:

- Television transmission, cellular networks, AM FM radio
- Lightning storms, solar activity
- Power transmission Lines
- Electronic devices such as computers, power supplies, motors, welders
- Intentional (weaponized) EMI

EMI Considerations

In data acquisition, electromagnetic interference (EMI) can cause reduction of signal quality and data loss due in the form of **noise** and or **drift**.

Consider the case of an analog signal transmitted from a sensor to a DAQ device.
What can be done to avoid issues associated with EMI?

Methods of reducing EMI affects:

- Proximity - reduce length of signal conductors to minimum, if possible locate on same PCB or in same enclosure
- Differential signal - double ended signals are preferred when EMI is expected and close proximity is not available
- Noise rejection cables/wires - twisted pair, foil shield, wire braided shield, combos

Available Hardware

- National Instruments
- Measurement Computing
- dSPACE
- Arduino or other

Available Hardware

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- Measurement Computing
- dSPACE
- Arduino or other

Available Hardware

Software Integration

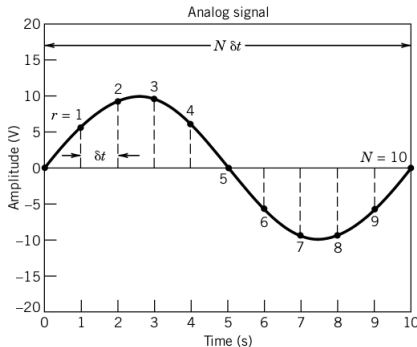
Software Integration

Topic 3 - Sampling and Aliasing

- Sampling
- The Aliasing Phenomenon
- Example by Hand
- MATLAB Example
- MATLAB Example

Sampling

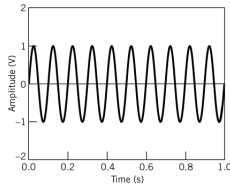
... A discrete time signal usually results from the sampling of a continuous variable at repeated finite time intervals. ...



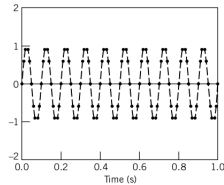
Discrete time signal	
$\{y(r\delta t)\}$	
r	Discrete data
0	0
1	5.9
2	9.5
3	9.5
4	5.9
5	0
6	-5.9
7	-9.5
8	-9.5
9	-5.9
10	0

Sampling

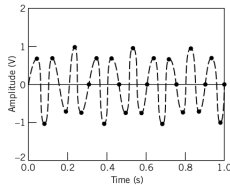
The Aliasing Phenomenon



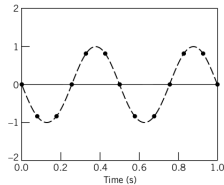
(a) Original 10-Hz sine wave analog signal



(b) $f_s = 100$ Hz



(c) $f_s = 27$ Hz



(d) $f_s = 12$ Hz

Figure: Theory and Design for Mechanical Measurements Ch. 7

Example by Hand

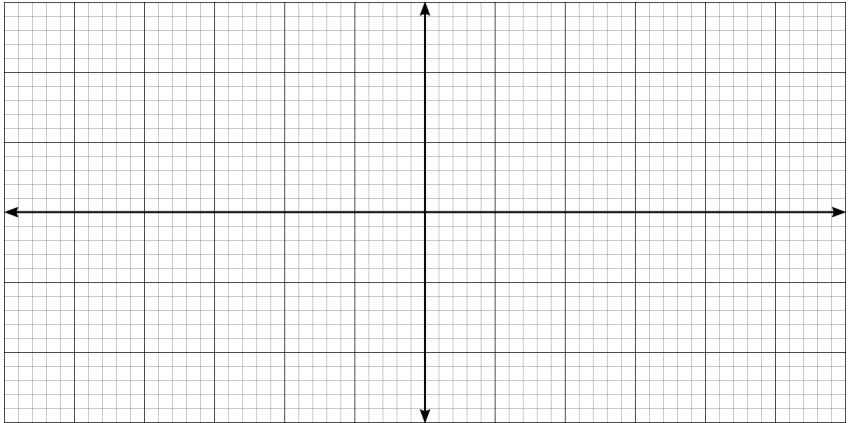


Image: T.Hill

Example by Hand

MATLAB Example

```
% ME3023 - Tennessee Technological University  
% Tristan Hill - October 10, 2019 - April 14,  
    2021  
% Data Acquisition Topic 3 - Sampling and  
    Aliasing
```

```
clear variables; close all; clc
```

```
% simulate a continuous signal  
A1=5; f1=3;  
w1=2*pi*f1;
```

```
dt_sim=0.001; t_stop=6;  
t_sim=0:dt_sim:t_stop;  
y_sim=A1*sin(w1*t_sim);
```

MATLAB Example

```
% simulate sampling the signal
dt_sam = 0.3;
t_sam=0:dt_sam:t_stop;
y_sam=A1*sin(w1*t_sam);

% show the figure
figure(1); hold on
plot(t_sim,y_sim,'-',t_sam,y_sam,'o')
axis([0 t_stop -1.2*A1 1.2*A1])
grid on
```

MATLAB code: T. Hill

Activity

Activity: Sampling Demonstration

Use the provided MATLAB program *samplingDemo.m* to accomplish the following:

- 1 Adjust the input signal frequency to plot a sinusoidal signal $y(t) = A \sin(\omega \cdot t) = A \sin(2\pi f \cdot t)$ with an amplitude $A = 1$ (units) and approximate frequency $f = 100$ (Hz). This is the *input signal*.
- 2 Adjust the sampling frequency until the sampled signal correctly represents the input amplitude. Find the minimum ratio of sampling frequency to input frequency that would allow for a reasonable measurement of amplitude.
- 3 Adjust the sampling frequency until the sampled signal correctly represents the input frequency. Find the minimum ratio of sampling frequency to input frequency that would allow for a reasonable measurement of frequency.

Deliverables: Submit answers to all discussion questions. Include a separate screen captures or saved images as justification for the answers to part 2 and part 3.